# EXHAUST EMISSION CONTROL APPARATUS FOR INTERNAL COMBUSTION ENGINE

The application incorporates by reference the subject matter of Application No. 2002-352951 filed in Japan on December 4, 2002, on which a priority claim is based under 35 U.S.C. § 119(a).

## BACKGROUND OF THE INVENTION

Field of the Invention

**[0001]** The present invention relates to an exhaust emission control apparatus for an internal combustion engine, and more particularly to a technique for reducing the emission of toxic substances and quickly activating a catalyst in an efficient manner while ensuring combustion stability when the internal combustion engine is started.

Description of the Related Art

**[0002]** Conventionally, it has been known that the reaction of unburned substances (such as HC and CO) and oxygen in an exhaust system (extending from a combustion chamber to an exhaust pipe) is accelerated by suppressing the flow of exhaust in the exhaust system (e.g. by increasing the exhaust pressure, increasing the exhaust concentration, increasing the period of time for which exhaust is retained, or causing exhaust to flow backward into cylinders), so that the emission of toxic substances can be reduced and a catalyst can be quickly activated when an internal combustion engine is cold-started.

[0003] However, if the flow of exhaust is suppressed (i.e. the exhaust pressure is increased) as above, the internal EGR (Exhaust Gas Recirculation) amount is increased, which may lead to deterioration of combustion state.

[0004] In particular, when the vehicle is accelerated from standstill, i.e. when the engine comes to operate at a low speed and with a high load applied thereto, combustion gas does not flow sufficiently in the cylinders due to low-speed revolution of the engine, and usually, during high load, the ignition timing is retarded so as to prevent knocking or the like, and also, when the engine is cold-started, the ignition timing is retarded so as to reduce the emission of exhaust gas. For this reason, combustion state is considerably deteriorated due to the increase in the internal EGR amount as above, and it is therefore difficult to ensure combustion stability. This is undesirable because the engine may stall immediately after starting.

[0005] Further, when the engine is idling with the flow of exhaust being suppressed, the negative pressure inside an intake manifold is low due to a small angle of opening of a throttle valve, and there is a significant difference between the internal pressure of the intake manifold and the exhaust pressure. For this reason, combustion gas is returned into an intake system to particularly increase the internal EGR amount, and when the vehicle is accelerated from standstill after idling, the internal EGR amount increases due to EGR gas which remains in the intake system during idling.

**[0006]** Therefore, there has been developed a technique for suppressing the EGR amount by reducing the valve overlap of intake and exhaust valves when the exhaust pressure is increased (refer to Japanese Laid-Open Patent Publication (Kokai) No. 8-158897, for example).

**[0007]** Also, there has been developed a technique for reducing the exhaust resistance when the engine is run at a high load applied thereto (refer to Japanese Laid-Open Patent Publication (Kokai) No. 3-117611, for example).

**[0008]** According to the technique disclosed in Japanese Laid-Open Patent Publication (Kokai) No. 8-158897, a variable valve timing mechanism is required for reducing the valve overlap. This is not desirable since costs are increased.

**[0009]** Also, the technique disclosed in Japanese Laid-Open Patent Publication (Kokai) No. 3-117611 has been developed by taking into account only the case where the engine is run with a load applied thereto, and has not been developed with combustion stability being taken into account. Thus, according to this technique, whenever a high-load operative state of the engine is detected, the exhaust resistance is lowered and thereafter is continuously lowered even if combustion stability can be ensured. Therefore, according to this technique, it is impossible to reduce the emission of toxic substances and quickly activate a catalyst in a satisfactory manner when the engine is started, and this is undesirable.

## SUMMARY OF THE INVENTION

[0010] It is therefore an object of the present invention to provide an exhaust emission control apparatus for an internal combustion engine, which is capable of reducing the emission of toxic substances and quickly activating a catalyst in an efficient manner while ensuring combustion stability when the engine is run at a low speed and with a high load applied thereto.

[0011] To attain the above object, there is provided an exhaust emission control apparatus for an internal combustion engine, comprising exhaust flow suppressing means provided in an exhaust system of the internal combustion engine mounted in a vehicle, for suppressing exhaust flow when the internal combustion engine is started; operative state detecting means for detecting whether the period of time elapsed after the vehicle starts accelerating from standstill is equal to or shorter than a predetermined period of time according to an operative state of the internal combustion engine; and exhaust flow control limiting means causes the exhaust flow control means to stop or reduce the suppression of exhaust flow when the operative state detecting means detects that the period of time elapsed after the vehicle starts accelerating from standstill is equal to or shorter than the predetermined period of time.

[0012] Specifically, when the operative state detecting means detects that the period of time elapsed after the vehicle starts accelerating from standstill is equal to or shorter than a predetermined period of time while the flow of exhaust is suppressed by the exhaust flow control means, the exhaust flow control limiting

means stops or reduces the suppression of exhaust flow over the predetermined period of time after the vehicle starts accelerating from standstill, and thereafter, when the period of time elapsed after the vehicle starts accelerating from standstill exceeds the predetermined period of time, the suppression of exhaust flow is resumed.

**[0013]** Since the suppression of exhaust flow is stopped or reduced when the internal combustion engine is started while the vehicle lies in the initial stage of accelerating from standstill, i.e. while the engine is run at a low speed and with a high load applied thereto, the internal EGR amount is prevented from increasing and deteriorating combustion state, and hence combustion stability can be ensured. Then, when the period of time elapsed after the vehicle starts accelerating standstill exceeds the predetermined period of time, i.e. when combustion stability can be ensured even if exhaust flow is suppressed, the suppression of exhaust flow is resumed. As a result, it is possible to minimize the period of time for which the suppression of exhaust flow is stopped or reduced, and reduce the emission of toxic substances and quickly activate a catalyst in a satisfactory manner.

**[0014]** Preferably, the operative state detecting means comprises load detecting means for detecting the load of the internal combustion engine, and engine speed detecting means for detecting the engine speed of the internal combustion engine, and the operative state detecting means detects that the period of time elapsed after the vehicle starts accelerating from standstill is equal to or shorter

than the predetermined period of time when the load detected by the load detecting means is equal to or greater than a predetermined load and the engine speed detected by the engine speed detecting means is equal to or lower than a predetermined engine speed.

[0015] Therefore, when the load detected by the load detecting means is equal to or higher than a predetermined load and the engine speed detected by the engine speed detecting means is equal to or lower than a predetermined engine speed, it can be easily detected that the period of time elapsed after the vehicle starts accelerating from standstill is equal to or shorter than a predetermined period of time according to the detected load and engine speed.

[0016] Preferably, the operative state detecting means comprises load detecting means for detecting the load of the internal combustion engine, and vehicle speed detecting means for detecting the vehicle speed, and the operative state detecting means detects the period of time elapsed after the vehicle starts accelerating from standstill is equal to or shorter than the predetermined period of time when the load detected by the load detecting means is equal to or greater than a predetermined load and the vehicle speed detected by the vehicle speed detecting means is equal to or lower than a predetermined vehicle speed.

[0017] Therefore, when the load detected by the load detecting means is equal to or higher than a predetermined load and the vehicle speed detected by the vehicle speed detecting means is equal to or lower than a predetermined engine speed, it can be easily detected that the period of time elapsed after the vehicle starts accelerating

from standstill is equal to or shorter than a predetermined period of time according to the detected load and engine speed.

[0018] Preferably, the operative state detecting means comprises cold state detecting means for detecting that the internal combustion engine is in cold state, and the exhaust flow control means suppresses the exhaust flow in the exhaust system when the internal combustion engine is started when the cold state detecting means detects that the internal combustion engine is in cold state within a predetermined temperature range.

[0019] Specifically, when the information supplied from the operative state detecting means indicates that the cold state detecting means detects that the internal combustion engine is in cold state within a predetermined temperature range, i.e. when combustion state is unlikely to deteriorate, the suppression of exhaust flow by the exhaust flow control means is not limited but the flow of exhaust is suppressed by the exhaust flow control means, so that the emission of toxic substances can be reduced and the catalyst can be quickly activated in a satisfactory manner.

[0020] Preferably, the exhaust flow control limiting means causes the exhaust flow control means to stop or reduce the suppression of exhaust flow when the cold state detecting means detects that the internal combustion engine is in cold state and is equal to or lower than a predetermined temperature.

[0021] Specifically, when the information supplied from the operative state detecting means indicates that the cold state detecting means detects that the internal combustion engine is in

cold state and is equal to or lower than a predetermined temperature, i.e. when combustion state is likely to deteriorate, the suppression of exhaust flow by the exhaust flow control means is stopped or reduced. As a result, it is possible to surely prevent deterioration of combustion state while ensuring combustion stability, and to minimize the period of time for which the suppression of exhaust flow is stopped or reduced.

**[0022]** Preferably, the exhaust flow control limiting means causes the exhaust flow control means to stop or reduce the suppression of exhaust flow when the operative state detecting means detects that the period of time elapsed after the vehicle starts accelerating from standstill is equal to or shorter than the predetermined period of time and the cold state detecting means detects that the internal combustion engine is in cold state and is equal to or lower than a predetermined temperature.

**[0023]** Specifically, when the information supplied from the operative state detecting means indicates that the period of time elapsed after the vehicle starts accelerating from standstill is equal to or shorter than a predetermined period of time and the cold state detecting means detects that the internal combustion engine is in cold state and is equal to or lower than a predetermined temperature (i.e. when combustion state is likely to deteriorate), the suppression of exhaust flow by the exhaust flow control means is stopped or reduced. As a result, it is possible to surely prevent deterioration of combustion state while ensuring combustion

stability, and to minimize the period of time for which the suppression of exhaust flow is stopped or reduced.

[0024] Preferably, the exhaust flow control limiting means comprises ignition timing control means for controlling ignition timing of the internal combustion engine, and the exhaust flow control limiting means causes the exhaust flow control means to stop or reduce the suppression of the exhaust flow and causes the ignition timing control means to retard the ignition timing when the operative state detecting means detects that the period of time elapsed after the vehicle starts accelerating from standstill is equal to or shorter than the predetermined period of time.

[0025] Specifically, when the internal combustion engine is run at a low speed and with a high load applied thereto, the ignition timing is usually retarded so as to prevent knocking or the like, and also, when the internal combustion engine is in cold state, the ignition timing is retarded so as to reduce the emission of exhaust gas, but the retard of the ignition timing deteriorates combustion state as described above, and hence in the case where the ignition timing is retarded, the ignition timing is advanced when the suppression of exhaust flow is stopped or reduced. As a result, it is possible to prevent deterioration of combustion state and ensure combustion stability while compensating for a delay in response of the exhaust flow control limiting means.

[0026] Preferably, the exhaust flow control limiting means comprises air-fuel ratio control means for controlling the air-fuel ratio of the internal combustion engine, and the exhaust flow control

limiting means causes the exhaust flow control means to stop or reduce the suppression of the exhaust flow and causes the air-fuel ratio control means to control the air-fuel ratio to a rich air-fuel ratio when the operative state detecting means detects that the period of time elapsed after the vehicle starts accelerating from standstill is equal to or shorter than the predetermined period of time.

**[0027]** Therefore, by controlling the air fuel ratio to a rich air-fuel ratio when the suppression of exhaust flow is stopped or reduced by the exhaust flow control limiting means, it is possible to surely prevent deterioration of combustion state and ensure combustion stability while satisfactorily compensating for a delay in response of the exhaust flow control limiting means.

**[0028]** Preferably, the operative state detecting means comprises idle time detecting means for detecting whether the exhaust flow is suppressed by the exhaust flow control means and the internal combustion engine has continued to idle for a predetermined period of time, and the exhaust flow control limiting means causes the exhaust flow control means to stop or reduce the suppression of the exhaust flow when the operative state detecting means detects that the period of time elapsed after the vehicle starts accelerating from standstill is equal to or shorter than the predetermined period of time and the idle time detecting means detects that the exhaust flow is suppressed by the exhaust flow control means and the internal combustion engine has continued to idle for the predetermined period of time.

[0029] Specifically, when the engine is idling in the state in which the period of time elapsed after the vehicle starts accelerating from standstill is equal to or shorter than a predetermined period of time and the exhaust flow control means suppresses the flow of exhaust, if it is detected that the engine has continued to idle for a predetermined period of time, the suppression of exhaust flow is then stopped or reduced.

[0030] As described above, when the engine is idling with the flow of exhaust being suppressed, the negative pressure inside an intake manifold is low due to a small angle of opening of a throttle valve, and there is a significant difference between the internal pressure of the intake manifold and the exhaust pressure. For this reason, combustion gas is returned into an intake system to particularly increase the internal EGR amount, and when the vehicle is accelerated from standstill after idling, the internal EGR amount increases as a result due to EGR gas which remains in the intake system during idling. According to the present invention, however, the suppression of exhaust flow is stopped or reduced to prevent deterioration of combustion state while ensuring combustion stability when the vehicle is accelerated from standstill, i.e. when the engine is run at a low speed and with a high load applied thereto.

[0031] Preferably, once the vehicle has been accelerated from standstill over a predetermined period of time, the engine is caused to idle again, and while the engine continues to idle for a predetermined period of time, the exhaust flow control means

suppresses the flow of exhaust. As a result, it is possible to minimize the period of time for which the suppression of exhaust flow is stopped or reduced, and to reduce the emission of toxic substances and quickly activate the catalyst in a satisfactory manner.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0032]** The nature of this invention, as well as other objects and advantages thereof, will be explained in the following with reference to the accompanying drawings, in which like reference character designate the same or similar parts throughout the figures and wherein;

**[0033]** FIG. 1 is a view schematically showing an exhaust emission control apparatus for an internal combustion engine according to the present invention;

**[0034]** FIG. 2 is a flow chart showing a control routine of starting time control according to a first embodiment of the present invention; and

**[0035]** FIG. 3 is a flow chart showing a control routine of starting time control according to a second embodiment of the present invention.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

**[0036]** The present invention will now be described in detail with reference to the drawings showing preferred embodiments thereof.

[0037] FIG. 1 is a view schematically showing the construction of an exhaust emission control apparatus for an internal combustion engine according to the present invention, which is mounted in a vehicle. A description will now be given of the construction of the exhaust emission control apparatus with reference to FIG. 1.

[0038] As shown in FIG. 1, an engine body (hereinafter referred to as "engine") 1 as the internal combustion engine is implemented by a multi port injection (MPI) type gasoline engine.

[0039] An ignition plug 4 is attached to a cylinder head 2 of each cylinder in the engine 1, and an ignition coil 8 which outputs a high voltage is connected to the ignition plug 4.

[0040] The cylinder head 2 of each cylinder is formed with an intake port 9, and an intake valve 11 which opens and closes in response to the movement of a cam of a cam shaft 12 which rotates in response to the revolution of the engine 1 and causes each intake port 9 to come into communication with or to be shut off from a combustion chamber 5. An end of an intake manifold 10 is connected to each intake port 9. An electromagnetic fuel injection valve 6 is attached to the intake manifold 10, and a fuel supply device, not shown, having a fuel tank is connected to the fuel injection valve 6 via a fuel pipe 7.

[0041] An electromagnetic throttle valve 17, which adjusts the quantity of intake air, and a throttle position sensor (TPS) 18, which detects the valve opening of the throttle valve 17, are provided upstream of the fuel injection valve 6 in the intake manifold 10.

[0042] The cylinder head 2 of each cylinder is formed with an exhaust port 13 in a substantially horizontal direction. An exhaust valve 15 which opens and closes according to the movement of a cam of a cam shaft 16 which rotates in response to engine revolution

and causes each exhaust port 13 to come into communication with or to be shut off from the combustion chamber 5 is provided at each exhaust port 13 and on the side of the combustion chamber 5. One end of an exhaust manifold 14 is connected to each exhaust port 13.

[0043] It should be noted that the MPI type engine 1 is publicly known, and hence detailed description thereof is omitted.

[0044] An exhaust pipe 20 is connected to the other end of the exhaust manifold 14, and a three-way catalytic converter 30 as an exhaust purifying catalytic device is disposed in the exhaust pipe 20. Further, an $O_2$ sensor 22 is disposed upstream of the three-way catalytic converter 30 in the exhaust pipe 20.

[0045] Further, an exhaust flow control device (exhaust flow control means) 40 is disposed downstream of the three-way catalytic converter 30 in the exhaust pipe 20.

[0046] The exhaust flow control device 40 is intended to promote reduction in toxic substances (such as $NO_X$, smoke, and $H_2$, as well as unburned substances HC and CO) included in exhaust gas, and is capable of changing at least one of exhaust pressure, exhaust concentration, and exhaust flow rate. Specifically, the exhaust flow control device 40 is comprised of a sealed type shut-off valve 42 which is capable of adjusting the passage area of the exhaust pipe 20.

[0047] A variety of types may be used for the sealed type shut-off valve 42, but it is assumed here that a butterfly valve is used.

The butterfly valve as the valve 42 is provided with an actuator 44 and is driven to open and close by the actuator 44.

**[0048]** An ECU (Electronic Control Unit) 40 is provided with an input/output device, storage devices (such as a ROM, a RAM, and a nonvolatile RAM), a central processing unit (CPU), a timer counter, and so forth, and collectively controls the component parts of the exhaust emission control apparatus including the engine 1.

**[0049]** Connected to an input of the ECU 10 are a variety of sensors such as a crank angle sensor 52 which detects the crank angle of the engine 1, a water temperature sensor (cold state detecting means) 54 which detects the cooling water temperature Tw of the engine 1, an accel position sensor (APS) (load detecting means) which detects the stroke of an accel pedal 55, i.e. the angle of opening of an accel, a vehicle speed sensor (vehicle speed detecting means) 58 which detects the vehicle speed V, an idle switch (SW) 59 which detects an idle state, as well as the above described TPS 18 and $O_2$ sensor 22, so that detection information from these sensors is input to the ECU 10. It should be noted that the engine speed Ne is detected based on information indicative of the crank angle output from the crank angle sensor 52 (engine speed detecting means).

**[0050]** On the other hand, a variety of output devices such as the above described fuel injection valve 6, ignition coil 8, throttle valve 17, and actuator 44 are connected to an output of the ECU 10. The fuel injection quantity, fuel injection timing, ignition timing, exhaust flow controlled variable calculated based on

detection information supplied from the variety of sensors are output to the output devices. As a result, the air-fuel ratio is controlled to a target air-fuel ratio, and a proper quantity of fuel is injected from the fuel injection valve 6 in proper timing (air-fuel ratio control means), and spark ignition is performed in proper timing by the ignition plug 4 (ignition timing control means). Further, the switching valve 42 is opened and closed in proper timing so that a desired exhaust flow control quantity (e.g. a target exhaust pressure) can be achieved.

**[0051]** More specifically, when the engine 1 is in a cold state, the exhaust emission control apparatus according to the present invention controls the flow of exhaust to quickly activate the three-way catalytic converter 30, and closes the shut-off valve 42 to suppress the flow of exhaust.

**[0052]** In this way, the exhaust pressure or the exhaust concentration in the exhaust system is increased to strengthen the engagement between unburned substances such as HC and CO and oxygen or $NO_X$ in the exhaust system to promote the reaction thereof, and therefore, the emission of toxic substances can be satisfactorily prevented, and the three-way catalytic converter 30 can be quickly activated due to an increase in exhaust temperature.

**[0053]** However, in the case where it is configured such that the flow of exhaust is suppressed immediately after starting of the engine 1 (i.e. immediately after the start of cranking), when the engine 1 is immediately accelerated from standstill to come into a low-speed/high-load operative state, the internal EGR amount

is increased to deteriorate combustion state since combustion gas does not sufficiently flow in the cylinders as described above when the engine 1 is operated at a low speed. Thus, combustion stability cannot be ensured, and hence there is the possibility that satisfactory accelerating performance cannot be achieved.

**[0054]** To address this problem, the exhaust emission control apparatus according to the present invention limits the suppression of exhaust flow in the case where the engine 1 comes into the low-speed/high-load operative state immediately after starting. A description will now be given of the operation of the exhaust emission control apparatus according to the present invention, which is configured as described above.

**[0055]** First, a first embodiment of the present invention will be described by referring to FIG. 2, which is a flow chart showing a control routine of starting time control according to the fist embodiment.

**[0056]** In Step S10, it is determined whether conditions for controlling the flow of exhaust have been satisfied or not. Specifically, it is determined whether or not the engine 1 is being cold-started, i.e. whether or not the cooling water temperature Tw of the engine 1 lies inside a predetermined temperature range (for example, temperatures lower than 50°C and higher than -10°C) and the period of time elapsed after starting of the engine 1 lies in a predetermined time range (for example, 10 to 100 seconds after starting of the engine 1). If the determination result is false (NO), i.e. it is determined that the above conditions have not been

satisfied, the process proceeds to Step S30 wherein the present routine is brought to an end without controlling the flow of exhaust, i.e. without suppressing the flow of exhaust. On the other hand, if the determination result in the Step S10 is true (YES), i.e. it is determined that the above conditions have been satisfied, the process proceeds to Step S12.

**[0057]** In the Step S12, it is determined whether or not the cooling water temperature Tw of the engine 1 is lower than a predetermined temperature T0 ($Tw<T0$) within the predetermined temperature range. Here, it is assumed that the predetermined temperature T0 is 0°C although it differs according to an engine to be used. Namely, in the Step S12, it is determined whether or not the engine 1 is colder than the predetermined temperature T0. If the determination result is true (YES), i.e. it is determined that the cooling water temperature Tw is lower than the predetermined temperature T0, the process proceeds to Step S14.

**[0058]** In the case where the engine 1 is accelerated from standstill according to driver's intension, it is determined in the Step S14 whether the period of time elapsed after the vehicle starts accelerating from standstill is equal to or shorter than a predetermined period of time (operative state detecting means). The predetermined period of time is set to a period of time which corresponds to the initial stage of acceleration from standstill before the engine 1 comes out of the low-speed/high-load operative state after the vehicle has been continuously accelerated. It is

assumed here that the predetermined period of time is set to three seconds although it differs according to an engine to be used.

[0059] Instead of or in addition to the determination as to whether the period of time elapsed after the vehicle starts accelerating from standstill is equal to or shorter than the predetermined period of time, it is possible to make a determination as to whether the period of time elapsed after the vehicle starts accelerating from standstill is equal to or shorter than a period of time which is required for the engine 1 to come out of the low-speed/high-load operative state. This determination is made according to whether or not an output value from the APS 56 detecting the stroke of the accel pedal 55 is equal to or greater than a predetermined value and the engine speed Ne is equal to or lower than a predetermined engine speed. Alternatively, this determination can be made according to whether or not an output value from the APS 56 detecting the stroke of the accel pedal 55 with the idle SW 59 off is equal to or greater than a predetermined value and the vehicle speed V is equal to or lower than a predetermined vehicle speed. It should be noted that whether the engine 1 has come out of the high-load operative state can be determined according to whether or not the volume efficiency is equal to or greater than a predetermined value, whether or not the net average effective pressure is equal to or greater than a predetermined value, or whether or not the idle SW 59 is off, instead of whether or not an output value of the APS 56 is equal to or greater than a predetermined value.

**[0060]** In this way, whether or not the period of time elapsed after the vehicle starts accelerating from standstill is equal to or shorter than the predetermined period of time can be easily determined.

**[0061]** If the determination result in the Step S14 is false (NO), i.e. it is determined that the engine 1 has not been accelerated from standstill or it is determined that a period of time elapsed after the vehicle starts accelerating from standstill is longer than the predetermined period of time, the process proceeds to Step S20 wherein exhaust flow control is provided to suppress the flow of exhaust.

**[0062]** Specifically, in the case where the engine 1 has not been accelerated from standstill or it is determined that the period of time elapsed after the start of accelerating from standstill is longer than the predetermined period of time, combustion stability does not matter, and hence the flow of exhaust is suppressed to prevent the emission of toxic substances and to quickly activate the three-way catalytic converter 30 by increasing the exhaust temperature. Therefore, it is possible to surely prevent the emission of toxic substances included in exhaust and to quickly activate the three-way catalytic converter 30 due to an increase in exhaust temperature.

**[0063]** On the other hand, if the determination result in the Step S14 is true (YES), i.e. it is determined that the period of time elapsed after the vehicle starts accelerating from standstill is equal to or shorter than the predetermined period of time, the

process proceeds to the Step S30 via Steps S16 and S18. In the Step S30, exhaust flow control is terminated to stop suppressing the flow of exhaust (exhaust flow control limiting means). Specifically, the suppression of exhaust flow is stopped over a period of time for which the engine 1 lies in the low-speed/high-load operative state, because the internal EGR amount is increased to cause deteriorated combustion as above in the case where the period of time elapsed after the vehicle starts accelerating from standstill is equal to or shorter than the predetermined period of time and the engine 1 lies in the low-speed/high-load operative state. As a result, combustion stability can be ensured, and desirable accelerating performance can be achieved.

**[0064]** By the way, when the engine 1 lies in the low-speed/high-load operative state, the ignition timing is usually retarded from reference timing so as to prevent knocking or the like. Also, when the engine 1 is in cold state, the ignition timing is retarded so as to reduce exhaust gas. However, as described above, the retard of the ignition timing leads to deterioration of combustion state, and hence in the case where the ignition timing is retarded, the suppression of exhaust flow is stopped, and the ignition timing is advanced in the Step S16. This prevents deterioration of combustion state and ensures combustion stability.

**[0065]** Further, even when an instruction for releasing exhaust flow control is output from the ECU 50, the shut-off valve 42 actually delays in response, and hence the suppression of exhaust flow cannot be immediately stopped. Therefore, when the exhaust flow control

limiting means stops the suppression of exhaust flow, the air-fuel ratio of the engine 1 is controlled to a rich air-fuel ratio. Therefore, a delay in response during exhaust flow control is satisfactorily compensated for, and as in the case where the ignition timing is advanced as above, the deterioration of combustion state can be prevented, and combustion stability can be ensured. It should be noted that the object can be attained only by compensating for a delay in response during exhaust flow control, and hence, after the air-fuel ratio is controlled o a rich air-fuel ratio, the air-fuel ratio may be gradually returned to a stoichiometric or lean air-fuel ratio. This prevents deterioration of fuel efficiency.

**[0066]** It should be noted that in the case where the ignition timing is retarded, a response delay in exhaust flow control can be compensated for by advancing the ignition timing as above.

**[0067]** Thereafter, if the determination result in the Step S14 is false (NO), i.e. it is determined that the period of time elapsed after the start of accelerating from standstill is longer than the predetermined period of time, the process proceeds to the Step S20 wherein exhaust flow control which has been stopped is resumed to suppress the flow of exhaust. Further, the advanced ignition timing is returned to the original, and the air-fuel ratio is returned to a stoichiometric or lean air-fuel ratio.

**[0068]** Specifically, in an intermediate high-speed range in which the period of time elapsed after the vehicle starts accelerating from standstill is longer than the predetermined period of time

and the engine 1 has come out of the low-speed/high-load operative state, the suppression of exhaust flow hardly causes deterioration of combustion state and has substantially no effect on accelerating performance. Therefore, the suppression of exhaust flow is resumed so that the emission of toxic substances can be prevented and the three-way catalytic converter 30 can be quickly activated due to an increase in exhaust temperature. Therefore, the period of time for which the suppression of exhaust flow is stopped can be minimized, and hence it is possible to reduce the emission of toxic substances and quickly activate the three-way catalytic converter 30 in an efficient manner.

**[0069]** Further, when the determination result in the Step S12 is false (NO), i.e. when the cooling water temperature Tw becomes equal to or higher than the predetermined temperature T0 (for example, 0°C), that is, if the cooling water temperature Tw becomes equal to or higher than the predetermined temperature T0 even though the engine 1 is still in cold state, the process proceeds to the Step S20 wherein exhaust flow control which has been stopped is resumed to suppress the flow of exhaust. Exhaust flow control is provided on condition that the cooling water temperature Tw of the engine 1 is equal to or higher than 0°C and lower than 50°C.

**[0070]** Specifically, if the cooling water temperature Tw of the engine 1 is not lower than the predetermined temperature T0, combustion state and accelerating performance hardly deteriorate even if the engine 1 is accelerated from standstill. In this case, even if the engine 1 is still in cold state, the suppression of

exhaust flow is resumed. This minimizes the period of time for which the suppression of exhaust flow is stopped, and therefore, it is possible to reduce the emission of toxic substances and quickly activate the three-way catalytic converter 30 in an efficient manner.

[0071] A description will now be given of a second embodiment of the present invention.

[0072] FIG. 3 is a flow chart showing a control routine of starting time control according to the second embodiment. It should be noted that in FIG. 3, the same steps as those appearing in FIG. 2 are denoted by the same reference numerals, and description thereof is omitted. Here, only steps different from those of the first embodiment will be described.

[0073] After the Step S10, if the determination result in the Step S12 is true (YES), i.e. it is determined that the cooling water temperature Tw is lower than the predetermined temperature T0, and if the determination result in the Step S14 is true (YES), i.e. it is determined that the period of time elapsed after the vehicle starts accelerating from standstill is equal to or shorter than the predetermined period of time, the process proceeds to Step S19.

[0074] In the Step S19, it is determined whether or not the engine 1 has continued to idle for a predetermined period of time (which is set to e.g. one second although it differs according to an engine to be used) during exhaust flow control (idling time detecting means). If the determination result in the Step S19 is false (NO), i.e. it is determined that the engine 1 has not continued to idle for the predetermined period of time, the process proceeds

to the Step S20 wherein exhaust flow control is provided to suppress the flow of exhaust. On the other hand, If the determination result in the Step S19 is true (YES), i.e. it is determined that the engine 1 has continued to idle for the predetermined period of time, the process proceeds to the Steps S16, S18, and S30 wherein exhaust flow control is released to stop the suppression of exhaust flow.

**[0075]** Specifically, when the engine 1 is idling with exhaust flow being suppressed, as described above, especially the internal EGR amount is likely to increase since combustion gas is returned into the intake system due to a small angle of opening of the throttle valve 17, a low negative pressure in the intake manifold 10, and a significant difference between the internal pressure of the intake manifold 10 and the exhaust pressure. When the vehicle is accelerated from standstill after idling, the internal EGR amount increases as a result due to EGR gas which remains in the intake system during idling. Accordingly, the suppression of exhaust flow is stopped to prevent the internal EGR amount from being increased when the engine 1 is accelerated from standstill, i.e. when the engine 1 lies in the low-speed/high-load operative state. Therefore, even if the vehicle is accelerated from standstill after idling, it is possible to prevent deterioration of combustion state while ensuring combustion stability.

**[0076]** It should be noted that once the vehicle is accelerated from standstill and the period of time elapsed after the vehicle starts accelerating from standstill becomes longer than the predetermined period of time, the determination result in the Step

S14 is false (NO), and the process proceeds to the Step S20 wherein exhaust flow control is provided to suppress the flow of exhaust. This minimizes the period of time for which exhaust flow is suppressed, making it possible to reduce the emission of toxic substances and quickly activate the three-way catalytic converter 30 in a satisfactory manner.

**[0077]** Although in the above described embodiments, exhaust flow control is released to stop the suppression of exhaust flow (Step S30), the present invention is not limited to this, but another exhaust flow control may be provided to limit the suppression of exhaust flow. In this case, in the step S20, exhaust flow control is provided based on the original suppression amount.

**[0078]** As described hereinabove, according to the exhaust emission control apparatus for the internal combustion engine according to the present invention, at cold-start of the engine 1, if the cooling water temperature Tw of the engine 1 is lower than the predetermined temperature T0 and the period of time elapsed after the vehicle starts accelerating from standstill is equal to or shorter than the predetermined period of time, the suppression of exhaust flow by exhaust flow control is stopped or reduced, and if the period of time elapsed after the vehicle starts accelerating from standstill exceeds the predetermined temperature T0, the suppression of exhaust flow is resumed.

**[0079]** Therefore, even in the case where the vehicle is accelerated from standstill at cold-start, the exhaust emission control apparatus according to the present invention can ensure

combustion stability by preventing combustion state from being deteriorated due to an increase in internal EGR amount, and minimize the period of time for which the suppression of exhaust flow is stopped or reduced so that the emission of toxic substances can be reduced and the catalyst can be quickly activated in an efficient manner.

**[0080]** Further, particularly in the case where the engine has continued to idle for the predetermined period of time during exhaust flow control when the vehicle is accelerated from standstill, exhaust flow control is limited to stop or reduce the suppression of exhaust flow.

**[0081]** Therefore, even if the vehicle is accelerated from standstill after idling during exhaust flow control, the internal EGR amount can be prevented from being increased due to EGR remaining in the intake system, and hence it is possible to ensure combustion stability by preventing deterioration of combustion state when the vehicle is accelerated from standstill.